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TISSUE PRODUCTS HAVING REDUCED LINT AND SLOUGH

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TISSUE PRODUCTS HAVING REDUCED LINT AND SLOUGH

Background of the Invention

Tissue products, such as facial tissues, paper towels, bath tissues, sanitary napkins, and other similar products, are designed to include several important properties. For example, the products should have good bulk, a soft feel, and should have good strength. Unfortunately, however, when steps are taken to increase one property of the product, other characteristics of the product are often adversely affected.

For example, during a papermaking process, it is common to use various resins to increase the wet strength of the web. Cationic resins, for example, are often used because they are believed to more readily bond to the anionically charged cellulosic fibers. In addition, resins that are anionic in nature have also been utilized. For example, U.S. Patent No. 3,844,880 to Meisel, Jr., et al. describes anionic styrene-butadiene latexes that are adhered to the anionic cellulosic fibers with a deposition aid.

Although strength resins can increase the strength of the web, they also tend to stiffen the web, which is often undesired by consumers. Thus, various methods are often used to counteract this stiffness and to soften the product. For example, chemical debonders can be utilized to reduce fiber bonding and thereby increase softness.

Nevertheless, reducing fiber bonding with a chemical debonder can sometimes adversely affect the strength of the tissue product. For example, hydrogen bonds between adjacent fibers can be broken by such chemical debonders, as well as by mechanical forces of a papermaking process. Consequently, such debonding results in loosely bound fibers that extend from the surface of the tissue product. During processing and/or use, these loosely bound fibers can be freed from the tissue

product, thereby creating lint, which is defined as individual airborne fibers and fiber fragments. Moreover, papermaking processes may also create zones of fibers that are poorly bound to each other but not to adjacent zones of fibers. As a result, during use, certain shear forces can liberate the weakly bound zones from the remaining fibers, thereby resulting in slough, i.e., bundles or pills on surfaces, such as skin or fabric. As such, the use of such debonders can often result in a much weaker paper product during use that exhibits substantial amounts of lint and slough.

As such, a need currently exists for a tissue product that is strong, soft, and that also has low lint and slough.

Summary of the Invention

In accordance with one embodiment of the present invention, a method is provided for forming a tissue product. The method includes providing a liquid furnish of cellulosic fibers and forming a multi-layered wet web from the liquid furnish of cellulosic fibers. At least one latex (e.g., nonionic or anionic) is applied to the furnish, wet web (e.g., sprayed), or combinations thereof in an amount less than about 60 pounds per ton of the dry weight of the cellulosic fibers, in some embodiments, between about 1 to about 40 pounds per ton of the dry weight of the cellulosic fibers, and in some embodiments, between about 1 to about 20 pounds per metric ton of the dry weight of the cellulosic fibers. The latex has a glass transition temperature that is less than about 30°C, and in some embodiments, that is also greater than about -25°C. For example, in some embodiments, the glass transition temperature is between about -15°C to about 15°C, and in some embodiments, between about -10°C to about 0°C. The latex can be selected from the group consisting of styrene-butadiene copolymers, polyvinyl acetate homopolymers, vinyl-acetate ethylene copolymers, vinyl-acetate acrylic copolymers, ethylene-vinyl chloride copolymers, ethylene-vinyl chloride-vinyl acetate

terpolymers, acrylic polyvinyl chloride polymers, acrylic polymers, and nitrile polymers.

A debonder is also be applied to the furnish, wet web, or combinations thereof. The total amount of debonder applied can be in an amount between about 1 to about 30 pounds per ton of the cellulosic fibers. In some embodiments, the debonder can contain an imidazoline quaternary compound and/or an ester-functional quaternary ammonium compound.

If desired, a wet strength agent (e.g., temporary or permanent) can also be applied to the furnish, wet web, or combinations thereof. For example, when utilized, the total amount of temporary wet strength agent applied can be in an amount between about 1 to about 60 pounds per ton of the dry weight of the cellulosic fibers. Moreover, when utilized, the total amount of permanent wet strength agent applied can be in an amount between about 1 to about 20 pounds per ton of the dry weight of the cellulosic fibers.

The wet web is then dried such that the resulting dried web has at least one outer layer containing the latex-treated cellulosic fibers.

Other features and aspects of the present invention are discussed in greater detail below.

Brief Description of the Drawings

A full and enabling disclosure of the present invention, including the best mode thereof to one of ordinary skill in the art, is set forth more particularly in the remainder of the specification, including reference to the accompanying figures in which:

Fig. 1 is a schematic flow diagram of one embodiment of a papermaking process that can be used in the present invention;

Fig. 2 is a schematic flow diagram of another embodiment of a papermaking process that can be used in the present invention;

Fig. 3 is a schematic flow diagram of still another embodiment of a papermaking process that can be used in the present invention; and

Fig. 4 is a schematic illustration of one example of an apparatus that can be used to measure the slough of a tissue product.

Repeat use of reference characters in the present specification and drawings is intended to represent same or analogous features or elements of the present invention.

Detailed Description of Representative Embodiments

Reference now will be made in detail to the embodiments of the invention, one or more examples of which are set forth below. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment, can be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

In general, the present invention is directed to a tissue product containing a multi-layered paper web that has at least one outer layer formed from cellulosic fibers treated with a latex. The latex can form a flexible bond with the cellulosic fibers such that the resulting web is flexible, strong, and produces low amounts of lint and slough. As used herein, a "tissue product" generally refers to various paper products, such as facial tissue, bath tissue, paper towels, napkins, and the like. Normally, the basis weight of a tissue product of the present invention is less than about 80 grams per square meter (gsm), in some embodiments less than about 60 grams per square meter, and in some embodiments,

between about 10 to about 60 gsm.

Any of a variety of materials can also be used to form the paper web(s) of the tissue product. For example, the material used to make the tissue product can include fibers formed by a variety of pulping processes, such as kraft pulp, sulfite pulp, thermomechanical pulp, etc. The pulp fibers may include softwood fibers having an average fiber length of greater than 1 mm and particularly from about 2 to 5 mm based on a length-weighted average. Such softwood fibers can include, but are not limited to, northern softwood, southern softwood, redwood, red cedar, hemlock, pine (e.g., southern pines), spruce (e.g., black spruce), combinations thereof, and the like. Exemplary commercially available pulp fibers suitable for the present invention include those available from Kimberly-Clark Corporation under the trade designations "Longlac-19".

Hardwood fibers, such as eucalyptus, maple, birch, aspen, and the like, can also be used. In certain instances, eucalyptus fibers may be particularly desired to increase the softness of the web. Eucalyptus fibers can also enhance the brightness, increase the opacity, and change the pore structure of the web to increase its wicking ability. Moreover, if desired, secondary fibers obtained from recycled materials may be used, such as fiber pulp from sources such as, for example, newsprint, reclaimed paperboard, and office waste. Further, other natural fibers can also be used in the present invention, such as abaca, sabai grass, milkweed floss, pineapple leaf, and the like. In addition, in some instances, synthetic fibers can also be utilized. Some suitable synthetic fibers can include, but are not limited to, rayon fibers, ethylene vinyl alcohol copolymer fibers, polyolefin fibers, polyesters, and the like.

As stated above, the tissue product of the present invention contains at least one multi-layered paper web. The tissue product can be a single-ply tissue product in which the web forming the tissue is stratified,

i.e., has multiple layers, or a multi-ply tissue product in which the webs forming the multi-ply tissue product may themselves be either single or multi-layered. For instance, in one embodiment, a tissue product contains a ply formed from three layers where the outer layers include eucalyptus fibers and the inner layer includes northern softwood kraft fibers. If desired, the layers may also include blends of various types of fibers. However, it should be understood that the tissue product can include any number of plies or layers and can be made from various types of fibers.

In accordance with the present invention, a latex is applied to the cellulosic fibers to reduce lint and slough of the resulting tissue product. As used herein, a "latex" generally refers to a natural or synthetic colloidal dispersion of a polymeric material in a liquid system that is primarily aqueous in nature. Latexes suitable for use in the present invention typically have a glass transition temperature less than about 30°C so that the flexibility of the resulting web is not substantially restricted. Moreover, the latexes also typically have a glass transition temperature greater than about -25°C to minimize the tackiness of the latex. For instance, in some embodiments, the latexes used in the present invention have a glass transition temperature between about -15°C to about 15°C, and in some embodiments, between about -10°C to about 0°C.

The latexes used in the present invention are typically nonionic or anionic to facilitate application to the paper web. For instance, some suitable latexes that can be utilized in the present invention include, but are not limited to, anionic styrene-butadiene copolymers, polyvinyl acetate homopolymers, vinyl-acetate ethylene copolymers, vinyl-acetate acrylic copolymers, ethylene-vinyl chloride copolymers, ethylene-vinyl chloride-vinyl acetate terpolymers, acrylic polyvinyl chloride polymers, acrylic polymers, nitrile polymers, and any other suitable anionic latex polymers known in the art. The charge (e.g., anionic or nonionic) of the latexes

described above can be readily varied, as is well known in the art, by utilizing a stabilizing agent having the desired charge during preparation of the latex. Other examples of suitable latexes may be described in U.S. Patent No. 3,844,880 to Meisel, Jr., et al., which is incorporated herein in its entirety by reference thereto for all purposes.

Although not required, the latex is typically applied to the cellulosic fibers at the "wet end" of a papermaking process. As used herein, the phrase "wet end" generally refers to any stage of the papermaking process that occurs either before or while the web is dried. For example, in some embodiments, the latex can be applied to the papermaking furnish at the pulper, dump chest, machine chest, clean stock chest, low density cleaner, added directly into the head box, etc. Moreover, the latex may also be applied after the furnish has been formed into a wet web. For instance, in some embodiments, the latex can be sprayed or printed onto the surface of a wet web. In one embodiment, for instance, a latex solution is sprayed onto the wet tissue web at any of a variety of different locations as the web courses through the papermaking machine.

Regardless of the particular location of the papermaking process at which the latex is added, at least one outer layer of the multi-layered paper web is incorporated with the latex. For instance, in one embodiment, the latex is incorporated into one outer layer of a three-layered paper web, which defines an outer surface of the tissue product. The presence of the latex in the outer layer(s) of the tissue product can reduce lint and slough produced by the tissue product.

To minimize the stiffness of the multi-layered paper web used to form the tissue product, a variety of different techniques can be utilized. For instance, the latex can be applied in relatively small amounts. In some embodiments, the latex is applied in an amount less than 60 pounds per ton (lb/T), in some embodiments between about 1 lb/T to about 40 lb/MT,

and in some embodiments, between about 1 lb/MT to about 20 lb/MT of the dry weight of fibrous material. In addition, the latex is also typically applied in amounts less than about 3%, in some embodiments between about 0.05% to about 2%, and in some embodiments, between about 0.05% to about 1% of the dry weight of fibrous material within a given layer. Further, in some embodiments, the latex is applied in amounts less than about 3%, in some embodiments between about 0.05% to about 2%, and in some embodiments, between about 0.05% to about 1% of the dry weight of the entire tissue product.

Further, the stiffness of the web can also be reduced by restricting application of the latex to only the outer layers of the web. For instance, in one embodiments, a three-layered paper web can be formed in which each outer layer contains the latex, while the inner layer is substantially free of the latex. In another embodiment, the inner layer and one outer layer of a three-layered web can be substantially free of the latex. It should be understood that, when referring to a layer that is "substantially free" of the latex, minuscule amounts of latex may be present therein. However, such small amounts often arise from the latex applied to the outer layer, and do not typically substantially affect the stiffness of the tissue product.

If desired, the latex can also be applied to the cellulosic fibers in conjunction with a deposition aid to facilitate retention of the latex on the fibers. For example, it may be useful to apply to the cellulosic fibers a "reactive composition". A reactive composition is a composition that can form a bond (e.g., covalent, ionic, etc.) with anionic groups located on the cellulosic fibers. For instance, in one embodiment, a cationic composition can be used to form an ionic bond with free carboxylic groups located on the fibers. Such a reactive composition can decrease the overall negative charge of the fibers, and in some instances, even impart a positive charge

to the fibers. Accordingly, the latex, when applied to fibers having such an altered charge, can more readily be retained thereon.

In general, any of a variety of reactive compositions can be applied to the cellulosic fibers to aid in deposition of the latex. Normally, it is also desired that such a reactive composition have additional functionality, e.g., strength and/or softness enhancement. For example, in some embodiments, a wet strength agent can be utilized, to further increase the strength of the tissue product, as well as to aid in the deposition of the latex. As used herein, a "wet strength agent" is any material that, when added to cellulosic fibers, can provide a resulting web or sheet with a wet geometric tensile strength to dry geometric tensile strength ratio in excess of about 0.1. Typically these materials are termed either "permanent" wet strength agents or "temporary" wet strength agents. As is well known in the art, temporary and permanent wet strength agents may also sometimes function as dry strength agents to enhance the strength of the tissue product when dry.

Wet strength agents may be applied in various amounts, depending on the desired characteristics of the tissue product. For instance, in some embodiments, the total amount of wet strength agents added to the cellulosic fibers can be between about 1 pound per ton (lb/T) to about 60 lb/T, in some embodiments, between about 5 lb/T to about 30 lb/T, and in some embodiments, between about 7 lb/T to about 13 lb/T of the dry weight of fibrous material. The wet strength agents can be incorporated into any layer of the multi-layered paper web.

Suitable permanent wet strength agents are typically water soluble, cationic oligomeric or polymeric resins that are capable of either crosslinking with themselves (homocrosslinking) or with the cellulose or other constituents of the wood fiber. Examples of such compounds are described in U.S. Pat. Nos. 2,345,543; 2,926,116; and 2,926,154, which

are incorporated herein in their entirety by reference thereto for all purposes. One class of such agents includes polyamine-epichlorohydrin, polyamide epichlorohydrin or polyamide-amine epichlorohydrin resins, collectively termed "PAE resins". Examples of these materials are described in U.S. Pat. Nos. 3,700,623 to Keim and 3,772,076 to Keim, which are incorporated herein in their entirety by reference thereto for all purposes and are sold by Hercules, Inc., Wilmington, Del. under the trade designation "Kymene", e.g., Kymene 557H or 557 LX. Kymene 557 LX, for example, is a polyamide epicholorohydrin polymer that contains both cationic sites, which can form ionic bonds with anionic groups on the pulp fibers, and azetidinium groups, which can form covalent bonds with carboxyl groups on the pulp fibers and crosslink with the polymer backbone when cured.

Other suitable materials include base-activated polyamide-epichlorohydrin resins, which are described in U.S. Pat. Nos. 3,885,158 to Petrovich; 3,899,388 to Petrovich; 4,129,528 to Petrovich; 4,147,586 to Petrovich; and 4,222,921 to van Eanam, which are incorporated herein in their entirety by reference thereto for all purposes. Polyethylenimine resins may also be suitable for immobilizing fiber-fiber bonds. Another class of permanent-type wet strength agents includes aminoplast resins (e.g., urea-formaldehyde and melamine-formaldehyde).

If utilized, the permanent wet strength agents can be added to the cellulosic fibers in an amount between about 1 lb/T to about 20 lb/T, in some embodiments, between about 2 lb/T to about 10 lb/T, and in some embodiments, between about 3 lb/T to about 6 lb/T of the dry weight of fibrous material.

Temporary wet strength agents can also be useful in the present invention. Suitable temporary wet strength agents can be selected from agents known in the art such as dialdehyde starch, polyethylene imine,

mannogalactan gum, glyoxal, and dialdehyde mannogalactan. Also useful are glyoxylated vinylamide wet strength resins as described in U.S. Pat. No. 5,466,337 to Darlington, et al., which is incorporated herein in its entirety by reference thereto for all purposes. Useful water-soluble resins include polyacrylamide resins such as those sold under the Parez trademark, such as Parez 631NC, by American Cyanamid Company of Stanford, Conn. Such resins are generally described in U.S. Patent Nos. 3,556,932 to Coscia, et al. and 3,556,933 to Williams, et al., which are incorporated herein in their entirety by reference thereto for all purposes. For example, the "Parez" resins typically include a polyacrylamide-glyoxal polymer that contains cationic hemiacetal sites that can form ionic bonds with carboxyl or hydroxyl groups present on the cellulosic fibers. These bonds can provide increased strength to the web of pulp fibers. In addition, because the hemicetal groups are readily hydrolyzed, the wet strength provided by such resins is primarily temporary.

U.S. Pat. No. 4,605,702 to Guerro, et al., which is incorporated herein in its entirety by reference thereto for all purposes, also describes suitable temporary wet strength resins made by reacting a vinylamide polymer with glyoxal, and then subjecting the polymer to an aqueous base treatment. Similar resins are also described in U.S. Patent Nos. 4,603,176 to Bjorkquist, et al.; 5,935,383 to Sun, et al.; and 6,017,417 to Wendt, et al., which are incorporated herein in their entirety by reference thereto for all purposes.

The temporary wet strength agents are generally provided by the manufacturer as an aqueous solution and, in some embodiments, is added to the cellulosic fibers in an amount between about 1 lb/T to about 60 lb/T, in some embodiments, between about 3 lb/T to about 40 lb/T, and in some embodiments, between about 4 lb/T to about 15 lb/T of the dry weight of fibrous material. If desired, the pH of the pulp can be adjusted

prior to adding the resin. The Parez resins, for example, are typically used at a pH of from about 4 to about 8.

A chemical debonder can also be applied to soften the web, as well as to aid in the deposition of the latex on the web. Specifically, a chemical debonder can reduce the amount of hydrogen bonds within one or more layers of the web, which results in a softer product. Depending on the desired characteristics of the resulting tissue product, the debonder can be utilized in varying amounts. For example, in some embodiments, the debonder can be applied in an amount in an amount between about 1 lb/T to about 30 lb/T, in some embodiments between about 3 lb/T to about 20 lb/T, and in some embodiments, between about 6 lb/T to about 15 lb/T of the dry weight of fibrous material. The debonder can be incorporated into any layer of the multi-layered paper web.

Any material that can be applied to cellulosic fibers and that is capable of enhancing the soft feel of a web by disrupting hydrogen bonding can generally be used as a debonder in the present invention. In particular, as stated above, it is typically desired that the debonder possess a cationic charge for forming an ionic bond with anionic groups present on the cellulosic fibers. Some examples of suitable cationic debonders can include, but are not limited to, quaternary ammonium compounds, imidazolinium compounds, bis-imidazolinium compounds, diquaternary ammonium compounds, polyquaternary ammonium compounds, ester-functional quaternary ammonium compounds (e.g., quaternized fatty acid trialkanolamine ester salts), phospholipid derivatives, polydimethylsiloxanes and related cationic and non-ionic silicone compounds, fatty & carboxylic acid derivatives, mono- and polysaccharide derivatives, polyhydroxy hydrocarbons, etc. For instance, some suitable debonders are described in U.S. Patent Nos. 5,716,498 to Jenny, et al.; 5,730,839 to Wendt, et al.; 6,211,139 to Keys, et al.;

5,543,067 to Phan, et al.; and WO/0021918, which are incorporated herein in their entirety by reference thereto for all purposes. For instance, Jenny, et al. and Phan, et al. describe various ester-functional quaternary ammonium debonders (e.g., quaternized fatty acid trialkanolamine ester salts) suitable for use in the present invention. In addition, Wendt, et al. describes imidazolinium quaternary debonders that may be suitable for use in the present invention. Further, Keys, et al. describes polyester polyquaternary ammonium debonders that may be useful in the present invention.

Still other suitable debonders are disclosed in U.S. Patent Nos. 5,529,665 to Kaun and 5,558,873 to Funk, et al., which are incorporated herein in their entirety by reference thereto for all purposes. In particular, Kaun discloses the use of various cationic silicone compositions as softening agents.

Although reactive compositions, such as described above, can be applied to the cellulosic fibers to aid in the deposition of the latex thereon, it should also be understood that such compositions may also be applied after application of the latex. In particular, the present invention is not limited to any specific order of application of the latex and the reactive compositions. For instance, in one embodiment, a latex, wet strength agent, and debonder can be sequentially applied to the web. In another embodiment, a wet strength agent, latex, and debonder can be sequentially applied to the web.

A tissue product made in accordance with the present invention can generally be formed according to a variety of papermaking processes known in the art. In fact, any process capable of making a paper web can be utilized in the present invention. For example, a papermaking process of the present invention can utilize wet-pressing, creping, through-air-drying, creped through-air-drying, uncreped through-air-drying, single

recreping, double recreping, calendering, embossing, air laying, as well as other steps in processing the paper web.

In some embodiments, in addition to the use of various chemical treatments, such as described above, the papermaking process itself can also be selectively varied to achieve a tissue product with certain properties. For instance, a papermaking process can be utilized to form a multi-layered paper web, such as described and disclosed in U.S. Pat. Nos. 5,129,988 to Farrington, Jr.; 5,494,554 to Edwards, et al.; and 5,529,665 to Kaun, which are incorporated herein in their entirety by reference thereto for all purposes.

In this regard, various embodiments of a method for forming a multi-layered paper web will now be described in more detail. Referring to Fig. 1, a method of making a wet-pressed tissue in accordance with one embodiment of the present invention is shown, commonly referred to as couch forming, wherein two wet web layers are independently formed and thereafter combined into a unitary web. To form the first web layer, a specified fiber (either hardwood or softwood) is prepared in a manner well known in the papermaking arts and delivered to the first stock chest 1, in which the fiber is kept in an aqueous suspension. A stock pump 2 supplies the required amount of suspension to the suction side of the fan pump 4. If desired, a metering pump 5 can supply an additive (e.g., latex, reactive composition, etc.) into the fiber suspension. Additional dilution water 3 also is mixed with the fiber suspension.

The entire mixture of fibers is then pressurized and delivered to the headbox 6. The aqueous suspension leaves the headbox 6 and is deposited on an endless papermaking fabric 7 over the suction box 8. The suction box is under vacuum that draws water out of the suspension, thus forming the first layer. In this example, the stock issuing from the

headbox 6 would be referred to as the "air side" layer, that layer eventually being positioned away from the dryer surface during drying.

The forming fabric can be any forming fabric, such as fabrics having a fiber support index of about 150 or greater. Some suitable forming fabrics include, but are not limited to, single layer fabrics, such as the Appleton Wire 94M available from Albany International Corporation, Appleton Wire Division, Menasha, Wis.; double layer fabrics, such as the Asten 866 available from Asten Group, Appleton, Wis.; and triple layer fabrics, such as the Lindsay 3080, available from Lindsay Wire, Florence, Miss.

The consistency of the aqueous suspension of papermaking fibers leaving the headbox can be from about 0.05 to about 2%, and in one embodiment, about 0.2%. The first headbox 6 can be a layered headbox with two or more layering chambers which delivers a stratified first wet web layer, or it can be a monolayered headbox which delivers a blended or homogeneous first wet web layer.

To form the second web layer, a specified fiber (either hardwood or softwood) is prepared in a manner well known in the papermaking arts and delivered to the second stock chest 11, in which the fiber is kept in an aqueous suspension. A stock pump 12 supplies the required amount of suspension to the suction side of the fan pump 14. A metering pump 5 can supply additives (e.g., latex, reactive composition, etc.) into the fiber suspension as described above. Additional dilution water 13 is also mixed with the fiber suspension. The entire mixture is then pressurized and delivered to the headbox 16. The aqueous suspension leaves the headbox 16 and is deposited onto an endless papermaking fabric 17 over the suction box 18. The suction box is under vacuum which draws water out of the suspension, thus forming the second wet web. In this example, the stock issuing from the headbox 16 is referred to as the "dryer side"

layer as that layer will be in eventual contact with the dryer surface. Suitable forming fabrics for the forming fabric 17 of the second headbox include those forming fabrics previously mentioned with respect to the first headbox forming fabric.

After initial formation of the first and second wet web layers, the two web layers are brought together in contacting relationship (couched) while at a consistency of from about 10 to about 30%. Whatever consistency is selected, it is typically desired that the consistencies of the two wet webs be substantially the same. Couching is achieved by bringing the first wet web layer into contact with the second wet web layer at roll 19.

After the consolidated web has been transferred to the felt 22 at vacuum box 20, dewatering, drying and creping of the consolidated web is achieved in the conventional manner. More specifically, the couched web is further dewatered and transferred to a dryer 30 (e.g., Yankee dryer) using a pressure roll 31, which serves to express water from the web, which is absorbed by the felt, and causes the web to adhere to the surface of the dryer. The web is then dried, optionally creped and wound into a roll 32 for subsequent converting into the final creped product.

Fig. 2 is a schematic flow diagram of another embodiment of a papermaking process than can be used in the present invention. For instance, a layered headbox 41, a forming fabric 42, a forming roll 43, a papermaking felt 44, a press roll 45, a Yankee dryer 46, and a creping blade 47 are shown. Also shown, but not numbered, are various idler or tension rolls used for defining the fabric runs in the schematic diagram, which may differ in practice. In operation, a layered headbox 41 continuously deposits a layered stock jet between the forming fabric 42 and the felt 44, which is partially wrapped around the forming roll 43. Water is removed from the aqueous stock suspension through the forming

fabric 42 by centrifugal force as the newly-formed web traverses the arc of the forming roll. As the forming fabric 42 and felt 44 separate, the wet web stays with the felt 44 and is transported to the Yankee dryer 46.

At the Yankee dryer 46, the creping chemicals are continuously applied on top of the existing adhesive in the form of an aqueous solution. The solution is applied by any convenient means, such as using a spray boom that evenly sprays the surface of the dryer with the creping adhesive solution. The point of application on the surface of the dryer 46 is immediately following the creping doctor blade 47, permitting sufficient time for the spreading and drying of the film of fresh adhesive.

In some instances, the latex, reactive compositions, etc., may be applied to the web as it is being dried, such as through the use of the spray boom. For example, the spray boom can apply the additives to the surface of the drum 46 separately and/or in combination with the creping adhesives such that such additives are applied to an outer layer of the web as it passes over the drum 46. In some embodiments, the point of application on the surface of the dryer 46 is the point immediately following the creping blade 47, thereby permitting sufficient time for the spreading and drying of the film of fresh adhesive before contacting the web in the press roll nip. Methods and techniques for applying an additive to a dryer drum are described in more detail in U.S. Patent Nos. 5,853,539 to Smith, et al. and 5,993,602 to Smith, et al., which are incorporated herein in their entirety by reference thereto for all purposes.

The wet web is applied to the surface of the dryer 46 by a press roll 45 with an application force of, in one embodiment, about 200 pounds per square inch (psi). Following the pressing or dewatering step, the consistency of the web is typically at or above about 30%. Sufficient Yankee dryer steam power and hood drying capability are applied to this web to reach a final consistency of about 95% or greater, and particularly

97% or greater. The sheet or web temperature immediately preceding the creping blade 47, as measured, for example, by an infrared temperature sensor, is typically about 235°F.

The web can also be dried using non-compressive drying techniques, such as through-air drying. A through-air dryer accomplishes the removal of moisture from the web by passing air through the web without applying any mechanical pressure. Through-air drying can increase the bulk and softness of the web. Examples of such a technique are disclosed in U.S. Patent Nos. 5,048,589 to Cook, et al.; 5,399,412 to Sudall, et al.; 5,510,001 to Hermans, et al.; 5,591,309 to Rugowski, et al.; and 6,017,417 to Wendt, et al., which are incorporated herein in their entirety by reference thereto for all purposes.

For example, referring to Fig. 3, one embodiment of a papermaking machine that can be used in forming an uncreped through-dried tissue product is illustrated. For simplicity, the various tensioning rolls schematically used to define the several fabric runs are shown but not numbered. As shown, a papermaking headbox 110 can be used to inject or deposit a stream of an aqueous suspension of papermaking fibers onto an upper forming fabric 112. The aqueous suspension of fibers is then transferred to a lower forming fabric 113, which serves to support and carry the newly-formed wet web 111 downstream in the process. If desired, dewatering of the wet web 111 can be carried out, such as by vacuum suction, while the wet web 111 is supported by the forming fabric 113.

The wet web 111 is then transferred from the forming fabric 113 to a transfer fabric 117 while at a solids consistency of between about 10% to about 35%, and particularly, between about 20% to about 30%. As used herein, a "transfer fabric" is a fabric that is positioned between the forming section and the drying section of the web manufacturing process.

In this embodiment, the transfer fabric 117 is a patterned fabric having protrusions or impression knuckles, such as described in U.S. Patent No. 6,017,417 to Wendt et al. Typically, the transfer fabric 117 travels at a slower speed than the forming fabric 113 to enhance the "MD stretch" of the web, which generally refers to the stretch of a web in its machine or length direction (expressed as percent elongation at sample failure). For example, the relative speed difference between the two fabrics can be from 0% to about 80%, in some embodiments greater than about 10%, in some embodiments from about 10% to about 60%, and in some embodiments, from about 15% to about 30%. This is commonly referred to as "rush" transfer. One useful method of performing rush transfer is taught in U.S. Pat. No. 5,667,636 to Engel et al., which is incorporated herein in its entirety by reference thereto for all purposes.

Transfer to the fabric 117 may be carried out with the assistance of positive and/or negative pressure. For example, in one embodiment, a vacuum shoe 118 can apply negative pressure such that the forming fabric 113 and the transfer fabric 117 simultaneously converge and diverge at the leading edge of the vacuum slot. Typically, the vacuum shoe 118 supplies pressure at levels between about 10 to about 25 inches of mercury. As stated above, the vacuum transfer shoe 118 (negative pressure) can be supplemented or replaced by the use of positive pressure from the opposite side of the web to blow the web onto the next fabric. In some embodiments, other vacuum shoes can also be used to assist in drawing the fibrous web 111 onto the surface of the transfer fabric 117.

From the transfer fabric 117, the fibrous web 111 is then transferred to the through-drying fabric 119. When the wet web 111 is transferred to the fabric 119. While supported by the through-drying fabric 119, the web 111 is then dried by a through-dryer 121 to a solids

consistency of about 95% or greater. The through-dryer 121 accomplishes the removal of moisture from the web 111 by passing air therethrough without applying any mechanical pressure. Through-drying can also increase the bulk and softness of the web 111. In one embodiment, for example, the through-dryer 121 can contain a rotatable, perforated cylinder and a hood for receiving hot air blown through perforations of the cylinder as the through-drying fabric 119 carries the web 11 over the upper portion of the cylinder. The heated air is forced through the perforations in the cylinder of the through-dryer 121 and removes the remaining water from the web 111. The temperature of the air forced through the web 111 by the through-dryer 121 can vary, but is typically from about 250°F to about 500°F. It should also be understood that other non-compressive drying methods, such as microwave or infrared heating, can be used.

As indicated above, the latex may sometimes be applied to the web as it courses through the papermaking machine. In one particular embodiment, for example, the latex may be sprayed onto the web. Spraying can enhance the ability of the latex to remain substantially on the outer layer of the web, thereby better inhibiting the production of slough therefrom. In general, the latex may be sprayed onto the web at any stage during its formation. For example, in the embodiment shown in Fig. 3, a spray nozzle 140 may spray the latex onto the web 111 after it is transferred to the fabric 117 and before it is dried. It should be understood, however, that the spray nozzle 140 may be positioned at any other location desired.

Any equipment suitable for spraying an additive onto a paper web may be utilized in the present invention. For instance, one example of suitable spraying equipment includes external mix, air atomizing nozzles, such as the 2 mm nozzle available from V.I.B. Systems, Inc., Tucker, Ga.

Another nozzle that can be used is an H 1/8" VV-SS 650017 VeeJet spray nozzle available from Spraying Systems, Inc. of Milwaukee, Wisconsin. Still other spraying techniques and equipment are described in U.S. Patent No. 5,164,046 to Ampulski, et al., which is incorporated herein in its entirety by reference thereto for all purposes.

In accordance with the present invention, it may sometimes be desired to control the retention % of the latex retained on the cellulosic fibers. Specifically, one or more variables, such as the sequence of application of the latex and reactive compositions, the type of latex, the type of reactive compositions, the amount of the latex and reactive compositions applied, etc., can be selectively altered so that the resulting retention % is within a desired range. For instance, in some embodiments, it may be desired that at least about 60% of the latex be retained on the fibers, and in some embodiments, between about 75% to about 90% of the latex be retained on the fibers.

The retention % of latex retained on the cellulosic fibers can be determined according the following formula:

$$\% \text{ retention} = 100 \times [(L_T - L_F)/L_T]$$

wherein,

L_T is the total amount of latex applied to a pulp slurry; and

L_F is the amount of latex remaining in the filtrate after removal of the pulp fibers therefrom. For example, L_F can be determined from the "turbidity" value of the filtrate. As used herein, the term "turbidity" generally refers to the optical clarity of a material and can be measured, for instance, using a Model DRT 100B Turbidimeter obtained from HF Scientific, Inc., which measures turbidity in terms of "Nephelometric Turbidity Units" (NTU). For instance, in one embodiment, a linear regression equation can be developed using known "L_F" values, e.g., $L_F = ax + b$, where "a" and "b" are constants; and "x" is the turbidity value.

By controlling the retention % of the latex, the strength and stiffness imparted to the tissue product can be appropriately balanced as desired. Moreover, relatively high retention percentages can allow a lower total level of latex to be used than if the retention percentage was relatively low. Accordingly, because a lower amount of latex is required, the present invention can provide a substantial cost reduction and enhanced efficiency to the papermaking process. Moreover, the resulting tissue product can be strong and produce a relatively low amount of lint and slough, while also maintaining the flexibility and softness desired for many end uses of the tissue product.

The present invention may be better understood with reference to the following examples.

EXAMPLE 1

The ability to determine latex retention from turbidity was demonstrated. A fibrous slurry was initially prepared from 100% bleached Kraft softwood pulp fibers. The slurry was slushed in a British disintegrator at a solids consistency of 1.6% for 5 minutes. The slurry was then diluted to a consistency of 0.33%.

Four samples of the fibrous furnish (volume of 909 ml and weight of 3 grams) were then removed from the pulp slurry and placed into a beaker. Thereafter, an anionic styrene-butadiene latex solution (available from Dow Chemical under the trade designation "DL-239"), having a solids content of 0.5% by weight of solution, was applied to each sample of the fibrous furnish in varying amounts as set forth below in Table 1.

Once applied with the latex, the furnish samples were diluted with water to a volume of 1000 ml. After waiting 10 minutes, the samples were filtered through the screen of a Freeness Tester according to TAPPI test method T227.

The filtrates from both the bottom and side orifices were collected

and mixed together for "turbidity" measurement. The presence of the anionic latex on a web of cellulosic material was detected by measuring the "turbidity" of the material. Specifically, a Model DRT 100B Turbidimeter obtained from HF Scientific, Inc. was first calibrated with a standard solution contained within in a test tube. 40 milliliters of the combined filtrates were then collected and added to the test tube. The test tube was then placed in the Turbidimeter, which contained a light source that provided light in a direction perpendicular to the tube. The resulting turbidity value was then read from the Turbidimeter and recorded.

The results for each sample were compared with a control sample that did not contain the pulp slurry. The results are shown below in Table 1.

Table 1: Turbidity Test Results

Sample	Amount of Latex (lbs/ton)	Turbidity	
		With Pulp Slurry	Without Pulp Slurry
Control	0	4.4	N/A
1	5	52	47
2	10	87	83
3	20	165	160
4	40	274	268

As indicated above, under the same amount of latex addition, the filtrate from the pulp slurry samples had slightly higher turbidity values than the control sample. Although not limited by theory, it is believed that this result is due to the fact that the small amount of pulp particles contributed to the turbidity value.

The amount of latex remaining in the filtrate after the fibers were screened off was then measured by developing a regression equation where the amount of latex remaining within the filtrate (lbs/ton of pulp)

was the "y" variable and the measured turbidity value of the control sample was the "x" variable. For the data provided in Table 1, the resulting regression equation was y = 0.1504x-1.8589, wherein the coefficient of correlation (R^2) was equal to 0.99.

EXAMPLE 2

The ability to incorporate latex into a fibrous furnish was demonstrated. A fibrous slurry was initially prepared from 100% bleached Kraft softwood pulp fibers. The slurry was slushed in a British disintegrator at a consistency of 1.6% for 5 minutes. The slurry was then diluted to a consistency of 0.33%.

Six samples of the fibrous furnish (volume of 909 ml and weight of 3 grams) were then removed from the pulp slurry and placed into a 1000 ml beaker. Thereafter, an anionic styrene-butadiene latex (available from Dow Chemical under the trade designation "DL-239"), having a solids content of 0.5% by weight of solution, was applied to each sample of the fibrous furnish in an amount of 20 lb/T. In addition, an imidazoline quaternary debonder (available from Hercules, Inc. under the trade designation "Prosoft TQ-1003") and "Parez" polyacrylamide temporary wet strength (also functions as dry strength agent) were also applied to the furnish in amount of 16.5 lb/T and 6.5 lb/T, respectively. The sequence of application for these additives was varied for each sample as set forth below in Table 2. A 5-minute interval existed between the application of each additive.

Once applied with the additives, the furnish samples were diluted with water to a volume of 1000 ml. After waiting 25 minutes, the samples were filtered through the screen of a Freeness Tester as set forth in Example 1. The turbidity and the amount of latex remaining in the filtrate were determined as set forth in Example 1. Once obtained, the value for the amount of latex remaining in the filtrate was then used to calculate the

retention % of anionic latex retained on various cellulosic webs according the following formula:

$$\% \text{ retention} = 100 \times [(L_T - L_F)/L_T]$$

wherein,

L_T is the total amount of latex applied to the pulp slurry; and

L_F is the amount of latex remaining in the filtrate after removal of the pulp fibers therefrom.

The results are provided in Table 2.

Table 2: Sample Results

Sample	1st Addition	2nd Addition	3rd Addition	Turbidity	Retention %
1	Debonder	Latex	Strength Agent	38	81
2	Latex	Debonder	Strength Agent	86	45
3	Strength Agent	Debonder	Latex	51	71
4	Debonder	Strength Agent	Latex	37	82
5	Latex	Strength Agent	Debonder	66	60
6	Strength Agent	Latex	Debonder	67	59

As shown, the sequence of chemical addition can have an effect on latex retention. For instance, samples 1 and 4, in which the debonder is added prior to the latex, provided the lowest turbidity coefficients.

EXAMPLE 3

The ability to incorporate latex into a fibrous furnish was demonstrated. A fibrous slurry was initially prepared from 100% bleached Kraft softwood pulp fibers. The slurry was slushed in a British disintegrator at a consistency of 1.6% for 5 minutes. The slurry was then diluted to a consistency of 0.33%.

Six samples of the fibrous furnish (volume of 909 ml and weight of 3 grams) were then removed from the pulp slurry and placed into a 1000 ml beaker. Thereafter, an anionic styrene-butadiene latex (available from Dow Chemical under the trade designation "DL-239"), having a solids content of 0.5% by weight of solution, was applied to each sample of the fibrous furnish in an amount of 20 lb/T. In addition, a diamidoamine quaternary debonder (available from Goldschmidt under the trade designation "Arosurf PA-727") and "Parez" polyacrylamide temporary wet strength agent (also functions as dry strength agent) were also applied to the furnish in amount of 16.5 lb/T and 6.5 lb/T, respectively. The sequence of application for these additives was varied for each sample as set forth below in Table 3. A 5-minute interval existed between the application of each additive.

Once applied with the additives, the furnish samples were diluted with water to a volume of 1000 ml. After waiting 25 minutes, the samples were filtered through the screen of a Freeness Tester as set forth in Example 1. The turbidity and retention % were then determined as set forth in Examples 1-2. The results are provided in Table 3.

Table 3: Sample Results

Sample	1st Addition	2nd Addition	3rd Addition	Turbidity	Retention %
1	Debonder	Latex	Strength Agent	66	60
2	Latex	Debonder	Strength Agent	60	64
3	Strength Agent	Debonder	Latex	48	73
4	Debonder	Strength Agent	Latex	55	68
5	Latex	Strength Agent	Debonder	55	68
6	Strength Agent	Latex	Debonder	45	75

As indicated, when utilizing a diamidoamine quaternary, the sequence of chemical addition did not have as large an effect on the turbidity coefficient than when using a imidazoline quaternary, as set forth in Example 2.

EXAMPLE 4

The ability to incorporate latex into a fibrous furnish was demonstrated. A fibrous slurry was initially prepared from 100% bleached Kraft softwood pulp fibers. The slurry was slushed in a British disintegrator at a consistency of 1.6% for 5 minutes. The slurry was then diluted to a consistency of 0.33%.

Six samples of the fibrous furnish (volume of 909 ml and weight of 3 grams) were then removed from the pulp slurry and placed into a 1000 ml beaker. Thereafter, an anionic styrene-butadiene latex (available from Dow Chemical under the trade designation "DL-239"), having a solids content of 0.5% by weight of solution, was applied to each sample of the fibrous furnish in an amount of 20 lb/T. In addition, a quaternized fatty acid trialkanolamine ester debonder (available from Goldschmidt under the trade designation "Varisoft We-16") and "Parez" polyacrylamide temporary wet strength agent (also functions as dry strength agent) were also applied to the furnish in amount of 16.5 lb/T and 6.5 lb/T, respectively. The sequence of application for these additives was varied for each sample as set forth below in Table 4. A 5-minute interval existed between the application of each additive.

Once applied with the additives, the furnish samples were diluted with water to a volume of 1000 ml. After waiting 25 minutes, the samples were filtered through the screen of a Freeness Tester as set forth in Example 1. The turbidity and retention % were then determined as set forth in Examples 1-2. The results are provided in Table 4.

Table 4: Sample Results

Sample	1st Addition	2nd Addition	3rd Addition	Turbidity	Retention %
1	Debonder	Latex	Strength Agent	47	74
2	Latex	Debonder	Strength Agent	43	77
3	Strength Agent	Debonder	Latex	33	85
4	Debonder	Strength Agent	Latex	44	76
5	Latex	Strength Agent	Debonder	47	74
6	Strength Agent	Latex	Debonder	40	79

As indicated, the quaternized fatty acid trialkanolamine ester debonder provided low turbidity coefficients, regardless of the sequence utilized.

EXAMPLE 5

The ability to incorporate latex into a fibrous furnish was demonstrated. A fibrous slurry was initially prepared from 100% bleached Kraft softwood pulp fibers. The slurry was slushed in a British disintegrator at a consistency of 1.6% for 5 minutes. The slurry was then diluted to a consistency of 0.33%.

Six samples of the fibrous furnish (volume of 909 ml and weight of 3 grams) were then removed from the pulp slurry and placed into a 1000 ml beaker. Thereafter, an anionic styrene-butadiene latex (available from Dow Chemical under the trade designation "DL-239"), having a solids content of 0.5% by weight of solution, was applied to each sample of the fibrous furnish in an amount of 20 lb/T. In addition, a dialkyldimethyl quaternary debonder (available from Goldschmidt under the trade designation "Varisoft 137") and "Parez" polyacrylamide temporary wet

strength agent (also functions as dry strength agent) were also applied to the furnish in amount of 16.5 lb/T and 6.5 lb/T, respectively. The sequence of application for these additives was varied for each sample as set forth below in Table 5. A 5-minute interval existed between the application of each additive.

Once applied with the additives, the furnish samples were diluted with water to a volume of 1000 ml. After waiting 25 minutes, the samples were filtered through the screen of a Freeness Tester as set forth in Example 1. The turbidity and retention % were then determined as set forth in Examples 1-2. The results are provided in Table 5.

Table 5: Sample Results

Sample	1st Addition	2nd Addition	3rd Addition	Turbidity	Retention %
1	Debonder	Latex	Strength Agent	60	65
2	Latex	Debonder	Strength Agent	81	48
3	Strength Agent	Debonder	Latex	80	49
4	Debonder	Strength Agent	Latex	56	67
5	Latex	Strength Agent	Debonder	56	67
6	Strength Agent	Latex	Debonder	57	66

As shown, the sequence of chemical addition can have an effect on latex retention on fiber. For instance, samples 4 and 5 provided low turbidity coefficients.

EXAMPLE 6

The ability to incorporate latex into a fibrous furnish was demonstrated. A fibrous slurry was initially prepared from 100% bleached Kraft softwood pulp fibers. The slurry was slushed in a British

disintegrator at a consistency of 1.6% for 5 minutes. The slurry was then diluted to a consistency of 0.33%.

Four samples of the fibrous furnish (volume of 909 ml and weight of 3 grams) were then removed from the pulp slurry and placed into a 1000 ml beaker. Thereafter, an anionic styrene-butadiene latex (available from Dow Chemical under the trade designation "DL-239"), having a solids content of 0.5% by weight of solution, was applied to each sample of the fibrous furnish in an amount of 20 lb/T.

In addition, "Prosoft TQ-1003", "Arosurf PA 727", Varisoft We-16", and "Varisoft 137" were applied respectively to Samples 1-4, each in an amount of 16.5 lb/T. "Kymene 557 LX", a polyamide epicholorohydrin permanent wet strength agent, was also applied to the furnish in amount of 8.5 lb/T. The sequence of application for these additives was debonder, strength agent, and then the latex. A 5-minute interval existed between the application of each additive.

Once applied with the additives, the furnish samples were diluted with water to a volume of 1000 ml. After waiting 25 minutes, the samples were filtered through the screen of a Freeness Tester as set forth in Example 1. The turbidity and retention % were then determined as set forth in Example 1. The results are provided in Table 6.

Table 6: Sample Results

Sample	Debonder	Turbidity	Retention %
1	Prosoft TQ-1003 (imidazoline quaternary)	20	94
2	Arosurf PA 727 (diamidoamine quaternary)	34	84
3	Varisoft we-16 (quaternized fatty acid trialkanolamine ester debonder)	24	91
4	Varisoft 137 (dialkyldimethyl quaternary)	41	78

As shown, ProsofTQ-1003 and Varisoft we-16 debonders provided the lowest turbidity coefficients.

EXAMPLE 7

The ability to form soft tissues that produce low amounts of slough was demonstrated. Nine tissue samples (Samples 7-15) were produced on a papermaking machine, such as illustrated in Fig. 1 and described above. Specifically, two separate tissue sheets were formed and couched together into a single sheet. The single sheet was then pressed, dried and creped. Separate stock chests were used to form each separate tissue sheet. The air-side stock chest contained northern softwood kraft fibers (LL-19, from Kimberly-Clark.), while the dryer-side stock chest contained eucalyptus fibers obtained from Bahil Su., Inc. For Samples 10-15, the LL-19 fibers were refined for 7 minutes with a refiner located below the stock chest. Each sample had a basis weight of 30 grams per square meter and contained 35% LL-19 softwood fibers and 65% eucalyptus fibers.

For Samples 7-9, "Kymene 557 LX", a polyamide epicholorohydrin permanent wet strength agent, was applied in an amount of 4 lb/T to the dryer-side stock chest and in an amount of 4 lb/T to the air-side stock chest. In addition, "Parez" polyacrylamide temporary wet strength agent (also functions as dry strength agent) was applied to the air-side stock pump in an amount of between 0 to about 3 lb/T.

For Samples 10-12, "Kymene 557 LX" was applied in an amount of 4 lb/T to the dryer-side stock chest and in an amount of 4 lb/T to the air-side stock chest. After mixing the slurry for approximately 15 minutes, 6 lbs/T of Mackernium DC-183, an imidazoline quaternary debonder available from McIntyre, Inc., was also added to the dryer-side stock chest. Further, "Parez" polyacrylamide temporary wet strength agent

(also functions as dry strength agent) was also applied to the air-side stock pump in an amount of between 0 to about 7.5 lb/T.

Samples 13-15 were formed in a manner identical to Samples 10-12, except that 20 lbs/T of Airflex A-105, a vinyl-acetate ethylene copolymer latex available from Air Products, was also added to the air-side stock chest. Further, "Parez" polyacrylamide temporary wet strength agent (also functions as dry strength agent) was applied to the air-side stock pump in an amount of between about 2 to about 10 lb/T.

Once formed, the tensile strength, slough, and stiffness of the samples were determined as follows.

Tensile strength

Tensile strength was reported as "GMT" (grams per 3 inches of a sample), which is the geometric mean tensile strength and is calculated as the square root of the product of MD tensile strength and CD tensile strength. MD and CD tensile strengths were determined using a MTS/Sintech tensile tester (available from the MTS Systems Corp., Eden Prairie, MN). Tissue samples measuring 3 inch wide were cut in both the machine and cross-machine directions. For each test, a sample strip was placed in the jaws of the tester, set at a 4 inch gauge length for facial tissue and 2 inch gauge length for bath tissue. The crosshead speed during the test was 10 in./ minute. The tester was connected with a computer loaded with data acquisition system; e.g., MTS TestWork for windows software. Readings were taken directly from a computer screen readout at the point of rupture to obtain the tensile strength of an individual sample.

Slough

In order to determine the abrasion resistance or tendency of the fibers to be rubbed from the web when handled, each sample was measured by abrading the tissue specimens via the following method.

This test measures the resistance of tissue material to abrasive action when the material is subjected to a horizontally reciprocating surface abrader. All samples were conditioned at 23°C ± 1°C and 50 ± 2% relative humidity for a minimum of 4 hours. Fig. 4 shows a diagram of the test equipment.

The abrading spindle contained a stainless steel rod, 0.5" in diameter with the abrasive portion consisting of a 0.005" deep diamond pattern extending 4.25" in length around the entire circumference of the rod. The spindle was mounted perpendicularly to the face of the instrument such that the abrasive portion of the rod extends out its entire distance from the face of the instrument. On each side of the spindle were located guide pins with magnetic clamps, one movable and one fixed, spaced 4" apart and centered about the spindle. The movable clamp and guide pins were allowed to slide freely in the vertical direction, the weight of the jaw providing the means for insuring a constant tension of the sample over the spindle surface.

Using a die press with a die cutter, the specimens were cut into 3" ± 0.05" wide x 8" long strips with two holes at each end of the sample. For the tissue samples, the MD direction corresponds to the longer dimension. Each test strip was then weighed to the nearest 0.1 mg. Each end of the sample was slid onto the guide pins and magnetic clamps held the sheet in place. The movable jaw was then allowed to fall providing constant tension across the spindle.

The spindle was then moved back and forth at an approximate 15 degree angle from the centered vertical centerline in a reciprocal horizontal motion against the test strip for 20 cycles (each cycle is a back and forth stroke), at a speed of 80 cycles per minute, removing loose fibers from the web surface. Additionally, the spindle rotated counter clockwise (when looking at the front of the instrument) at an approximate

speed of 5 RPMs. The magnetic clamp was then removed from the sample and the sample was slid off of the guide pins and any loose fibers on the sample surface are removed by blowing compressed air (approximately 5-10 psi) on the test sample. The test sample was then weighed to the nearest 0.1 mg and the weight loss calculated. Ten test samples per tissue sample were tested and the average weight loss value in milligrams was recorded.

Stiffness

Stiffness (or softness) was ranked on a scale from 0 to 16, where lower values represent softer tissues and higher values represent stiffer tissues. Twelve (12) panelists were asked to consider the amount of pointed, rippled or cracked edges or peaks felt from the sample while turning in your hand. The panelists were instructed to place two tissue samples flat on a smooth tabletop. The tissue samples overlapped one another by 0.5 inches (1.27 centimeters) and were flipped so that opposite sides of the tissue samples were represented during testing. With forearms/elbows of each panelist resting on the table, they placed their open hand, palm down, on the samples. Each was instructed to position their hand so their fingers were pointing toward the top of the samples, approximately 1.5 inches (approximately 3.81 centimeters) from the edge. Each panelist moved their fingers toward their palm with little or no downward pressure to gather the tissue samples. They gently moved the gathered samples around in the palm of their hand approximately 2 to 3 turns. The rank assigned by each panelist for a given tissue sample was then averaged and recorded.

The results are provided below in Table 7.

Table 7: Sample Results

Sample	GMT (grams/3 inches)	Slough (mg)	Panel Stiffness
7	572	6.37	3.0
8	583	5.78	2.9
9	623	8.27	3.0
10	513	12.34	2.4
11	445	10.38	2.4
12	638	18.71	2.7
13	884	9.56	2.9
14	729	10.33	2.8
15	433	7.88	2.4

As indicated from the results set forth in Table 7, the addition of a latex in accordance with the present invention can provide a soft tissue product that is strong and produces relatively low amounts of slough.

EXAMPLE 8

The ability to form soft tissues that produce low amounts of slough was demonstrated. Three tissue samples (Samples 16-18) were formed as described above and shown in Fig. 3, with the exception that the uncreped through-dried tissue was formed from two separate sheets couched together into a single sheet, such as shown in Fig. 1.

The bottom sheet of the tissue was formed from a head box having two layers. The lower layer of the two-layered headbox was supplied with eucalyptus fibers obtained from Bahil Su., Inc. and the upper layer of the two-layered headbox was supplied with northern softwood kraft fibers (LL-19, from Kimberly-Clark.). The top sheet was formed from eucalyptus fibers obtained from Bahil Su., Inc. Each layer of the tissue had its own stock system including stock chest, metering pump, fan pump and white water handling. Each tissue sample had a basis weight of 30 grams per square meter and contained 40% LL-19 softwood fibers and 60% eucalyptus fibers (split equally between each sheet).

For Sample No. 16, 4.5 lb/T "Parez" polyacrylamide temporary wet strength agent (also functions as a dry strength agent) and 16.5 lb/T of Mackernium DC-183, a imidazoline quaternary debonder available from McIntyre, Inc., were applied to the eucalyptus stock chests supplied to the two-layered headbox and top sheet. In addition, 8 lb/T "Parez" polyacrylamide temporary wet strength agent (also functions as dry strength agent) was applied to the LL-19 stock pump. The LL-19 fibers were subjected to 10 minutes refining with a refiner located below the stock chest.

Sample 17 was prepared in an identical manner to Sample 16, except that 10 lb/T of Airflex A-105, a vinyl-acetate ethylene copolymer latex available from Air Products, was sprayed onto the eucalyptus layer of the lower sheet between the rush transfer section and the through-air dryer (See Fig. 3) while the sheet had a solids consistency of about 20%. The latex was sprayed onto the sheet using an H 1/8" VV-SS 650017 VeeJet spray nozzle available from Spraying Systems, Inc. of Milwaukee, Wisconsin. The nozzle sprayed the latex onto the sheet at a 65° angle to the sheet at a rate of 0.017 gallons per minute and a pressure of 40 pounds per square inch. In addition, 6 lb/T "Parez" polyacrylamide temporary wet strength agent (also functions as dry strength agent) was applied to the LL-19 stock pump.

Sample 18 was prepared in an identical manner to Sample 17, except that the latex utilized was an anionic styrene-butadiene latex available from Dow Chemical under the trade designation "DL-239". In addition, 7 lb/T "Parez" polyacrylamide temporary wet strength agent (also functions as dry strength agent) was applied to the LL-19 stock pump.

Once formed, the tensile strength, slough, and stiffness of the samples were determined as set forth in Example 7. The results are provide below in Table 8.

Table 8: Sample Results

Sample	GMT (grams/3 inches)	Slough (mg)	Panel Stiffness
16	896	9.50	4.47
17	707	7.36	4.53
18	823	6.83	4.69

As indicated from the results set forth in Table 8, the addition of a latex in accordance with the present invention can provide a soft tissue product that is strong and produces relatively low amounts of slough.

While the invention has been described in detail with respect to the specific embodiments thereof, it will be appreciated that those skilled in the art, upon attaining an understanding of the foregoing, may readily conceive of alterations to, variations of, and equivalents to these embodiments. Accordingly, the scope of the present invention should be assessed as that of the appended claims and any equivalents thereto.